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HEALTH IMPLICATIONS OF POLYNUCLEAR AROMATIC HYDROCARBONS IN ST. LOUIS PARK DRINKING WATER

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DIVISION OF ENVIRONMENTAL HEALTH
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INTRODUCTION

This report is an assessment of the risk associated with the contamination of the St. Louis Park drinking water supply by the creosote wastes in the soil near the former Republic Creosote site in St. Louis Park. Republic Creosote was engaged in coal tar distillation and the impregnation of wood with creosote for over 50 years. During that time substantial areas of land south of the site became contaminated with creosote wastes.

In 1974 the Minnesota Department of Health issued a report entitled, "Report on Investigation of Phenol Problem in Private and Municipal Wells in St. Louis Park, Minnesota". The report included data on phenols in St. Louis Park municipal wells which indicated that many of the wells contained low levels of phenolic compounds. The report also made a number of recommendations relatin to the need for further hydrological and epidemiological studies.

In November, 1975, the Minnesota Pollution Control Agency contracted with a local BARR REPORT engineering firm to conduct a study of soils and hydrology of the site area to identify the extent and nature of the contamination problem. The results of the study indicate that coal tar wastes have contaminated large areas of soils and that ground water in the water table aquifer is very contaminated near the site. The study also demonstrated the complexity of the soils and the bedrock geology in the site area and the difficulties which can be expected in using mathematical models to predict the flow of ground water in the site area.

In October, 1977, the Minnesota Department of Health released a report entitled, "Assessment of Possible Human Health Effects Resulting from the Contamination of the Former Republic Creosote Site". The report made quantitative worst-case projections of the level of human health risk from the spread of carcinogenic materials in the wastes to municipal drinking water wells in the area. These projections indicated that it is possible the coal tar wastes are having a significant impact on the public's health. The report went on to make a number of recommendations for future hydrological, epidemiological, and environmental studies to provide the data needed for a more complete assessment of health risk. One of those recommendations was for a study of the municipal wells in the area to determine the concentration of specific polynuclear aromatic hydrocarbons (PAH). The first phase of the PAH in drinking water study has been completed and this report is an assessment of the study's findings.

PAH IN DRINKING WATER

During the period May 8, 1978 to August 9, 1978, samples were taken from municpal drinking water wells in the communities of St. Louis Park, Edina, Robbinsdale, White Bear Lake, and Fridley; and from four private residential water wells in Edina, and the Glenwood-Englewood water well in Robbinsdale. Samples of Minneapolis and St. Paul drinking water were collected November 8, 1978. The data are contained in Table 1.

The St. Louis Park, Edina Public and Private wells, and the Robbinsdale wells were sampled to determine if creosote waste from the Republic Creosote site has reached any municipal drinking water supplies. These communities were selected for the study because they use ground water as a potable water source, they are geographically near the Republic Creosote site, and positive phenol values have in the past been detected in some of the wells in the general area. The Fridley and White Bear Lake samples were taken for use as controls. Minneapolis and St. Paul were sampled to determine PAH exposure from a surface water supply. Golden Valley, Crystal, and New Hope are near St. Louis Park, but since they purchase their water from Minneapolis they were not part of the sampling program. Samples were not taken from the municipal water supplies of Plymouth, Minnetonka, or Hopkins because, although they are near St. Louis Park, the Barr Engineering study of the Republic site showed the general direction of ground water flow to be to the east. The results of the present study indicate the assumption that these communities are upstream from the flow of contaminated water may be in error and it is the intention of the

Health Department to sample all of these communities in the future. A sample was collected from the Glenwood-Englewood well because of its proximity to the Republic site and because water from the well is bottled and sold commercially. The location of the St. Louis Park and Edina wells sampled are shown in Figure 1. Figure 2 is a general map of the area.

Analysis of the water samples was performed by high performance liquid chromatography using a modification of a method developed by the U. S. Environmental Protection Agency.(1) The method consists of liquid-liquid extraction of two liters of water with cyclohexane followed by direct injection of the concentrated extract into a high performance liquid chromatograph (HPLC). The samples were scanned for all PAH compounds detectable by fluorescent HPLC. Unequivocal positive results were obtained for the PAH compounds pyrene, fluoranthene, anthracene, and naphthacene. Identification of these compounds was confirmed by gas chromatography/mass spectrometry. The values expressed as "less than" were below the detection limit which was defined as four times the peak-to-peak noise of the HPLC baseline. Positive values near the detection limit may result by chance inflections of the HPLC baseline and may not represent true PAH concentrations.

Samples were taken from all wells used by St. Louis Park as a source of potable water. Examination of the data indicates that for St. Louis Park, wells 10 and 15 are the most heavily contaiminated while wells 7 and 9 are contaminated to a lesser degree and well 14 to a still lesser degree. All of these wells are in the Shakopee-Jordan aquifer at depths ranging from 446 to 503 feet below the surface. The most distant contaminated well is number 14 which is 1.73 miles from the creosote waste disposal area. The contaminants present are the PAH compounds pyrene, fluoranthene, anthracene and naphthacene. All these contaminants have been shown to be present in high concentration in the contaminated soils and ground water on or near the Republic site.

Samples from both the public and private Edina wells, the Robbinsdale wells, and the Glenwood-Englewood well were negative. The control wells in White Bear Lake and Fridley as well as the Minneapolis and St. Paul samples were also negative.

There are some values above the detection limit for benzo(a) pyrene (BaP), benzo(ghi)perylene (BghiPe), and o-phenylenepyrene (oPP). These values are close to the detection limit and they cannot be unequivocally interpreted as reflecting the actual presence of these compounds. However, the fact that most of these positive values occur in the five contaminated wells, suggests these compounds may actually be present in low concentrations.

The geographical distribution of positive values indicates the contamination is flowing generally northward and that the probable source of the contamination is the Republic site. The northerly spread of the contamination reflects the complexity of the ground water flow patterns in the areas since the direction of flow in the Shakopee-Jordan is generally considered to be eastward. (2)

The unexpected direction of flow of the contamination suggests further well monitoring studies are needed to better define the spread of the contamination. Also, the St. Louis Park municipal wells should be resampled and analyzed for PAH using more sensitive procedures to determine whether or not low levels of BaP, BghiPe, and oPP are present.

CARCINOGENICITY AND MUTAGENICITY STUDIES

Since the levels of specific PAH compounds in the St. Louis Park drinking water supply are relatively low, we will not in this assessment address the question of the classical toxic effects which might accompany ingestion of high concentrations. Since chronic exposure to subacute concentrations of PAH has been shown to cause cancer in human populations, we will confine ourselves to whether or not ingestion of the PAH compounds present in the St. Louis Park water supply has the potential to produce carcinogenesis in the exposed population.(3) To aid in this discussion we will point out some common operational definitions of certain terms which are commonly used to describe chemical carcingens and related compounds. Complete carcinogens are chemicals which when applied to the tissues of an animal in a sufficiently high dose will cause tumors to appear. Carcinogenic initiators are compounds which after a single dose, produce changes which cause tumors to appear if a carcinogenic promoting agent is routinely applied. Co-carcinogens are chemicals which will produce tumors if applied to animal tissue simultaneously, but are incapable of causing tumorigenic response if applied independently.

We will now summarize the specific laboratory studies which have investigated the tumorigenic effects of the four compounds found to be present in the St. Louis Park water supply. Some reviews of chemical carcinogenesis list these four compounds as inactive.(4) While it is clear that none of the compounds are powerful complete carcinogens such as B[a]P, they have been shown to possess properties which suggest they may play a role in human carcinogenesis.

A number of laboratory studies in animal systems have demonstrated the tumorigenic activity of pyrene. In one study pyrene carried in a noncarcinogenic vehicle (Decalin) and a 50:50 mixture of Decalin and n-dodecane (a known carcinogen) was applied topically to C3H male mice for 80 weeks.[5] Under these conditions pyrene showed a low level of tumorigenic response which required the addition of the dodecane cocarcinogen. These data show pyrene to be a cocarcinogen.

Several investigators have tested the cocarcinogenic ability of a number of compounds to enhance the tumorigenic effect of benzo(a)pyrene. In a more complete study by Van Duuren and Goldshmidt the test compounds, including pyrene and fluoranthene, were applied three times weekly to the skin of female ICR/Ha Swiss mice with a low dose (5 μgm) of B(a)P.[6] Both pyrene and fluoranthene remarkably increased both the number of mice with tumors and the total number of tumors. Fluoranthene also significantly decreased the time of the appearance of the first tumor. These data indicate pyrene and fluoranthene are potent cocarinogens. The study also tested the tumor promoting effects of certain compounds to an initial subcarcinogenic dose of B(a)P. The results indicate that both fluoranthene and pyrene may be weak promoters, but the results are somewhat inconclusive.

Salaman and Roe found that anthracene may be a tumor initiator when followed by repeated application of croton oil, a well-known promoter.[7] In a more recent study by Scribner of tumor initiating abilities of certain hydrocarbons, eight-week-old female CD-1 mice were treated once with the test compound and then twice weekly with a powerful tumor promoting agent.[8] Pyrene and anthracene produced tumors in 17 percent and 14 percent of the test animals respectively. Essentially no tumors appeared in the control group. These data demonstrate pyrene and anthracene are capable of initiating tumorigenic response in a mouse skin system.

Corwin et al., found a significant increase in the formation of melanotic tumors in first and second-generation progeny of Drosophila melanogaster males and females which had been exposed chronically as larvae to low concentrations of anthracene. The results were consistent with the interpretation that anthracene induces autosomal dominant melanotic tumor mutations in Drosophila.[9]

Naphthacene is a compound which is not generally considered to be carcinogenic but which has been subjected to very little testing.[4,10] The absence of direct evidence of carcinogenic response is not, however, reason to consider exposure to naphthacene unimportant. A review of chemical carcinogenesis by Buu-Hoi states the following:

> "It is clear, therefore, that many carcinogens exist among hydrocarbons derived from naphthacene and their aza analogs and that a high degree of chemical reactivity and susceptibility to addition-reactions (of the Diels-Alder diene-synthesis type) do not necessarily exclude carcinogenicity. Relevant to these observations is the pronounced activity displayed by naphthacene itself as an inducer of microsomal enzyme synthesis (azo dye N-de-methylase and zoxazolamine hydroxylase) during a study made recently by Arcos, Conney, and Buu-Hoi on a larger number of polycyclic hydrocarbons of different molecular sizes."

The statement suggests that carcinogenic compounds may be formed from naphthacene; however, we lack data on the possible tumorigenic effects of this compound.

A number of in vitro test systems for carcinogens have recently been developed using mammalian cell cultures. The ability of a chemical to transform mammalian cells in culture has been correlated with carcinogenicity in animal systems. The advantage of screening chemicals with the in vitro system is that the test can be completed in a matter of weeks or months rather than years as is required for most animal studies. Anthracene and fluoranthene were tested in an in vitro system and found to transform rat embryo cells, although the results were somewhat variable.[11] Pyrene was tested in a similar system and found to be not active.[12]

PAH have been shown to bind to DNA in vivo[13] and in vitro.[14,15] These studies have been directed toward elucidating the mechanism of carcinogenicity and have demonstrated, in the opinion of some investigators, a direct relationship between the degree of covalent binding to DNA and the carcinogenic power of the hydrocarbon.[13,16] In a study of such binding potential, anthracene was tested along with such powerful carcinogens as benzo(a)pyrene and dibenz(a,h) anthracene.[17] Under the conditions of this study, anthracene was bound to a higher degree than any of the hydrocarbons tested. The results of the study were interpreted as indicating that there was no direct relationship between binding and carcinogenicity since anthracene was not at that time considered to have carcinogenic properties, even though the rest of the hydrocarbons tested bound to DNA roughly in proportion to their carcinogenic strength. Altho studies of this type cannot be related directly to human carcinogenesis, it does indicate that anthracene has an important property in common with compounds that are generally considered to be probable human carcinogens.

In summary, studies have shown that anthracene and pyrene are capable of initiating tumorigenesis in a two stage mouse skin system. Pyrene and fluoranthene have been shown to be powerful cocarcinogens, enhancing the carcinogenic effect of benzo(a)pyrene. Anthracene and fluoranthene were found to be capable of transforming mammalian cells *in vitro*, a property which has been correlated with carcinogenicity, and anthracene has been found to have DNA binding characteristics similar to those of powerful carcinogens.

ASSESSMENT OF RISK

We have quantified the ingested exposure to the four contaminants, pyrene, fluoranthene, anthracene, and naphthacene, and the fact that three of them have been shown to possess carcinogenic or cocarcinogenic properties in laboratory experiments. Our task now is to use this information to assess the health risk associated with exposure of the inhabitants of St. Louis Park to these materials. Ideally, this would involve the evaluation of human epidemiological data from which one could obtain dose-response relationship which could be used to calculate cancer incidence or mortality from data on the PAH in drinking water exposure in St. Louis Park. Unfortunately, /there are no epidemiological studies of human exposure to any of these compounds other than those dealing with a complex mixture of chemicals. Such data cannot be used to obtain dose-response relationships for single compound exposures or for our particular mixture of four compounds because synergistic, antagonistic, cocarcinogenic, and promoting reactions depend on the specific nature of the mixture. Also, none of the epidemiologic studies which have been done relate to exposure by ingestion./

In the absence of adequate human epidemiological data, an alternative approach is to estimate a dose-response from long-term animal studies. However, the compounds in the St. Louis Park water supply are cocarcinogens and the health impact they might have is dependent on an interaction with other compounds to which the population is exposed. Since we do not have quantitative data on exposure to these other compounds, we cannot model the St. Louis Park situation using exising animal data.

A third way to assess the risk associated with use of the St. Louis Park water supply is to determine if the contaminant levels exceed any established standards. The only drinking water standards for PAH compounds are the guidelines of the World Health Organization and the Commission of European Communities.[18,19] These guidelines state that whenever the sum ~~of the concentrations of six specifically~~ listed PAH compounds exceed 200 nanograms/liter, the water should not be used for human consumption. One of these six compounds is fluoranthene. Fluoranthene ~~in St. Louis Park~~ wells 10 and 15 averaged 321 nanograms/liter, clearly exceeding the recommended standard.

A fourth possible approach to risk assessment is to determine how the drinking water exposure compares with exposures normally encountered by the population to the same compounds from other sources. If we find the drinking water exposures are significantly greater than or equivalent to those normally experienced we will not have added greatly to our knowledge since we still will not have a quantitative estimate of the risk involved. If however we find the drinking water exposures are significantly less than normal exposures we will be able to at least establish the risk is relatively small.

In applying this approach we will compare drinking water exposure only with other ingested exposures. Although measurable quantities of PAH materials are present in urban atmospheres, inhaled PAH should not be compared with ingested PAH since absorption rates are different for the two routes of entry to the body and chemicals absorbed through the lung do not make a first pass through the liver where metabolic activation and/or detoxification processes may occur. Some inhaled particulate material is moved up the bronchial tree and eventually ingested, but the extent to which this occurs for PAH in particulate form is not accurately known. Therefore, since we lack information with which to convert inhaled PAH to equivalent ingested exposures, it is necessary to ignore airborn PAH exposure. However, inhaled PAH to a large extent reach the blood stream and are distributed widely throughout the body exposing the same organs as ingested PAH. To the extent this occurs our calculations which will ignore inhaled PAH, will underestimate the true normal exposure.

For our comparison we shall also ignore the possibility of a naturally occurring PAH exposure from drinking water since the data from water supplies in the Minneapolis-St. Paul area indicates there is very little of these materials normally present. We will consider only the pyrene, fluoranthene and anthracene, content of a normal diet for our comparison, since there are essentially no data on the naphthacene content of foodstuffs.

PAH in food, especially smoked food, has been studied by a number of investigators. The incidence of stomach cancer in Iceland is very high and it has been suggested that the causal agent is PAH in smoked fish and other smoked foods.[20,21] Bailey found the following levels of PAH in smoked fish.

Pyrene	0.7 - 5.9 μg/kilogram
Fluoranthene	0.0 - 4.6 μg/kilogram
Anthracene	1.3 - 19.8 μg/kilogram

A large survey of smoked foods conducted by the U. S. Department of Agriculture found that smoked and barbecued meats contain pyrene(0.2 - 3.2 μg/kg) and fluoranthene(0.6 - 2.9 μg/kg).[22] Howard, et al., found somewhat higher values for smoked foods, pyrene(0.5 - 11.2 μg/kg) and low levels in unsmoked food, pyrene (0.8 - 1.6 μg/kg) and fluoranthene(0.7 - 1.4 μg/kg).[23] Pyrene and fluoranthene have also been found in low concentrations in most kinds of vegetable oils.[24]

Roasted coffee also contains PAH materials.[25] A popular brand of commercially available coffee contained 5 μg of pyrene per 1000 grams and 1 μg of fluoranthene per 1000 grams. The source of PAH in roasted coffee is smoke from the fire used in the roasting process.

Composite diet samples have also been found to contain low levels of pyrene and fluoranthene.[26] Although quantitative data is not available for these samples, the maximum measured values for pyrene and fluoranthene was 2 μg/kg.

Perhaps the most important source of dietary PAH in the United States is charcoal broiled meats. Steaks prepared on a charcoal fire have been found to contain pyrene(35 μg/kg), fluoranthene(43 μg/kg), and anthracene (0.6 μg/kg).[27] Also ground beef cooked in a way typical for the preparation of hamburgers has been shown to contain substances which are mutagenic in the Ames system.[28]

A complete listing of PAH in foodstuffs would obviously be desireable for use in calculating the average daily PAH intake from food. Unfortunately, there is not data available on PAH in a wide variety of foodstuffs. Because we lack complete data, some assumptions about the content of the three compounds of interest must be made in order to estimate total normal ingested exposure. We will therefore assume the previously mentioned values for charcoal broiled steak are present in all steak consumed by the population of St. Louis Park. We will further assume that all other solid foodstuffs contain the relatively low concentrations of 1 μg/kg for pyrene and fluoranthene and 0.05 μg/kg for anthracene and that coffee contains the same levels as were found in the study by Masanori. We will not single out smoked foods for separate consideration because the levels of pyrene, fluoranthene, and anthracene found in smoked foods in the United States are not that much different from the levels we assumed for solid foodstuffs and the quantity of smoked foods consumed is low. The assumption relating to PAH levels in other solid foodstuffs is not adequately supported by any one study, but the data on PAH in foods generally suggests the stated levels.

We must now estimate the quanitity of steak, coffee, and total weight of foodstuffs consumed by the St. Louis Park population. Since St. Louis Park is an affluent urban community, we will use food consumption data for urban households with incomes in excess of $10,000.00 in North Central United States for 1965.[29] The use of these rather old data will represent an error in the PAH intake estimate to the extent food consumption patterns have changed since 1965. From these data one calculates the quantity of steak consumed by the average person is about 60 grams per day, the amount of coffee is about 16 grams per day, and the total quanitty of solid foodstuffs is about 1200 grams per day. Using these values and the assumed PAH concentrations one obtains the following values for normal ingested intake of PAH.

(Micrograms/Day)	Steak	Other Solid Food	Coffee	Total
Pyrene	2.1	1.2	0.1	3.4
Fluoranthene	2.6	1.2	-	3.8
Anthracene	0.04	0.06	-	0.1

We shall now compare these dietary estimates with the calculated drinking water PAH exposure to the population of St. Louis Park. The highest PAH concentrations occur at wells 10 and 15 which are contaminated to about the same extent. Duplicate sampling has revealed some variability in PAH concentrations of wells 10 and 15 and we therefore shall use for our comparison the maximum measured value for each compound so as to lessen the chance of underestimating the actual concentration. Because of dilution from uncontaminated wells the entire population of St. Louis Park is not exposed to PAH at this maximum level; however, this estimate should not be far off for a large percentage of the population. If we assume an average water intake per person of two liters one obtains:

	Water Concentration Nanograms/Day	Intake from Water Supply Micrograms/Day
Pyrene	1221	2.4
Fluoranthene	450	0.9
Anthracene	241	0.5

For pyrene and fluoranthene the drinking water exposure is less than the estimated dietary intake and for anthracene it is greater. Since a number of assumptions were made in arriving at dietary intake, there is a good possibility these estimates may be off by as much as a factor of ten in either direction. The estimate of maximum exposure from drinking water is less likely to be in error and is intentionally biased toward a high value. Therefore, one can conclude the ingested intake of PAH from the St. Louis Park water supply may increase the normal ingested exposure of the three compounds, but most likely not by more than about a factor of ten.

It is difficult to judge the effect of such a tenfold increase; however, one cannot rule out the possibility of an impact on the health of the residents of St. Louis Park. Since the PAH concentration at wells 7 and 9 are for pyrene within a factor of ten of our maximum values, the use of these wells may also represent a hazard. PAH in well 14 is still lower and does not at this time present a hazard.

This dietary comparison indicates exposure to pyrene, fluoranthene, and anthracene from the St. Louis Park drinking water supply represents a potential health hazard. Because of the almost total lack of data on the occurrence and carcinogenicity of naphthacene we can make no such comparison for this compound. However naphthacene is a reactive four ring PAH compound and nearly all carcinogenic PAH are four or five ringed compounds. This similarity to other carcinogens and our general lack of knowledge about naphthacene supports our conclusion that exposure to these materials is potentially hazardous.

CONCLUSIONS

From the data and analysis presented herein, one can conclude the following:

1) PAH compounds in wells 10 and 15 exceed the recommended international drinking water standards of the World Health Organization and the Commission of European Communities. Also, the use of the St. Louis Park water supply may significantly increase the intake of PAH compounds which have been shown to possess carcinogenic properties in laboratory studies or to have chemical properties similar to known carcinogens. Therefore, the continued use of St. Louis Park water wells 7, 9, 10, and 15 represents a potential hazard to the public's health and steps should be taken as soon as possible to remove the PAH contaminants from the water prior to its distribution or to eliminate its use.

2) The concentration of PAH in St. Louis Park well 14 is not high enough at the present time to represent a hazard and no limitation on its use can be justified by this study.

3) The water samples taken from wells in Edina, Robbinsdale, Fridley, White Bear Lake, and the Glenwood-Englewood well showed these water supplies are as yet not contaminated with PAH compounds.

4) The geographical distribution of the contaminated St. Louis Park wells suggest the source of the contamination is the former Republic Creosote site. The major direction of spread of contamination as indicated by this study

is to the north; however, there may also be significant contamination in areas not included in this study and the negative results for the unaffected St. Louis Park wells and the Edina wells do not rule out future problems in these areas.

5) The water supplies of communities to the north and west of St. Louis Park and the private wells to the east, which were not included in this study should be sampled and analyzed for the presence of PAH contaminants.

6) The St. Louis Park water supply should be periodically sampled for PAH at a number of locations in the distribution system to determine the effect dilution with water from uncontaminated wells, the magnitude of any seasonal variations in PAH concentrations, and the actual population dose distribution.

7) The five contaminated St. Louis Park wells should be analyzed using more sensitive methods for B[a]P, B[ghi]Pe, and oPP. In addition a variety of laboratory detection systems should be used to look for non-fluorescing PAH compounds.

TABLE I*

ppt.

PAH in Drinking Water

(Nanograms/Liter)

	Well	Depth (feet)	Aquifer	anthracene A	Pyrane P	Flour FI	BaP	BghiPE	OPP	Napthacene N
	SLP #3	236	FSP	< 1.9	< 47	<0.9	<1.1	< 4.4	< 1.1	<10
closed	SLP #4	500	SJ	< 1.9	< 47	4.5	<1.1	< 4.4	< 1.1	<10
	SLP #5	465	SJ	< 1.9	< 47	7.4	<1.0	< 4.1	< 1.2	<10
	SLP #6	480	SJ	< 1.9	< 47	<1.0	<1.0	< 4.8	< 1.5	<10
closed	SLP #7	446	SJ	• 11.4	104	7.4	<1.1	< 4.4	< 1.1	<10
	SLP #8	507	SJ	< 1.9	< 47	<0.8	<1.1	< 4.4	< 1.1	<10
closed	SLP #9	473	SJ	• 12.2	199	21.1	<1.1	< 4.4	< 1.1	<10
closed	SLP #10	500	SJ	• 100	800	450	<1.1	< 9.8	< 2.1	-
	SLP #10	500	SJ	• 54	486	152	1.3	4.4	< 1.2	80
	SLP #11	1000	H	< 1.9	< 47	< 0.9	<1.1	< 4.5	< 1.1	<10
	SLP #12	1095	H	< 1.9	< 47	< 0.9	<1.1	< 4.5	< 1.1	<10
	SLP #13	1040	H	< 1.9	< 47	1.0	<1.1	< 4.5	< 1.2	<10
	SLP #13	1040	H	< 1.9	< 47	< 0.9	<1.2	< 4.9	< 1.1	<10
	SLP #14	485	SJ	• 6.3	< 47	4.2	1.8	5.5	2.2	<10
	SLP #14	485	SJ	• 6.3	< 47	2.4	<1.2	5.4	< 1.1	<10
closed	SLP #15	503	SJ	• 190	750	390	<1.2	<10.7	< 2.4	-
	SLP #15	503	SJ	• 241	1221	292	1.5	6.8	2.0	160
	SLP #16	500	SJ	< 1.9	< 47	< 0.8	<1.1	< 4.4	< 1.1	<10
	Edina #2	460	SJ	< 1.9	< 47	3.1	<1.1	< 4.6	< 1.1	<10
	Edina #3	475	SJ	< 1.9	< 47	1.0	<1.1	< 4.6	< 1.1	<10
	Edina #4	495	SJ	< 1.9	< 47	0.9	<1.1	< 4.6	< 1.1	<10
	Edina #7	547	SJ	< 1.9	< 47	<0.8	<1.1	< 4.7	< 1.1	<10
	Edina #15	405	SJ	< 1.9	< 47	<0.8	<1.1	< 4.6	< 1.1	<10
	Edina #17	461	SJ	< 1.9	< 47	<0.8	<1.1	< 4.7	< 1.1	<10
	R #1	624	SJ	< 1.9	< 48	2.8	<1.2	< 4.9	< 1.1	<10
	R #2	624	SJ	< 1.9	< 47	2.1	<1.2	< 4.9	< 1.1	<10
	R #4	402	SJ	< 1.9	< 47	0.9	<1.2	< 4.9	< 1.1	<10
	WBL #3	289	SJ	< 1.9	< 48	<1.0	<1.0	< 5.1	< 1.6	<10
	F #13	332	SJ	< 1.9	< 48	1.5	<1.2	< 6.3	< 2.0	<10
	Edina P #1	-	-	< 1.8	< 45	2.1	<0.8	5.6	< 1.2	<10
	Edina P #2	-	-	< 1.8	< 45	1.2	<0.8	< 3.4	< 1.2	<10

Well	Depth (feet)	Aquifer	A	P	Fl	BaP	BghiPE	oPP	N
Edina P #3	-	-	< 1.8	<45	2.3	<0.8	3.9	< 1.2	< 10
Edina P #4	-	-	< 1.8	<45	< 0.8	<0.8	< 3.4	< 1.2	< 10
Glenwood Englewood	-	-	< 1.9	<47	< 0.9	<1.2	6.8	1.6	< 10
Minneapolis	-	-	< 7.0	<210	9.3	<3.6	<13.0	< 1.7	-
St. Paul	-	-	< 7.0	<210	4.7	<3.6	<13.0	< 1.7	-

* < = less than detection limit, A = anthracene, P = pyrene, Fl = fluoranthene, BaP = benzo[a]pyrene, BghiPe = benzo[ghi]perylene, oPP = o-phenylenepyrene, SLP = St. Louis Park, R = Robbinsdale, F = Fridley, WBL = White Bear Lake, PSP = Platteville-St. Peter, SJ = Shakopee-Jordan, H = Hinkley

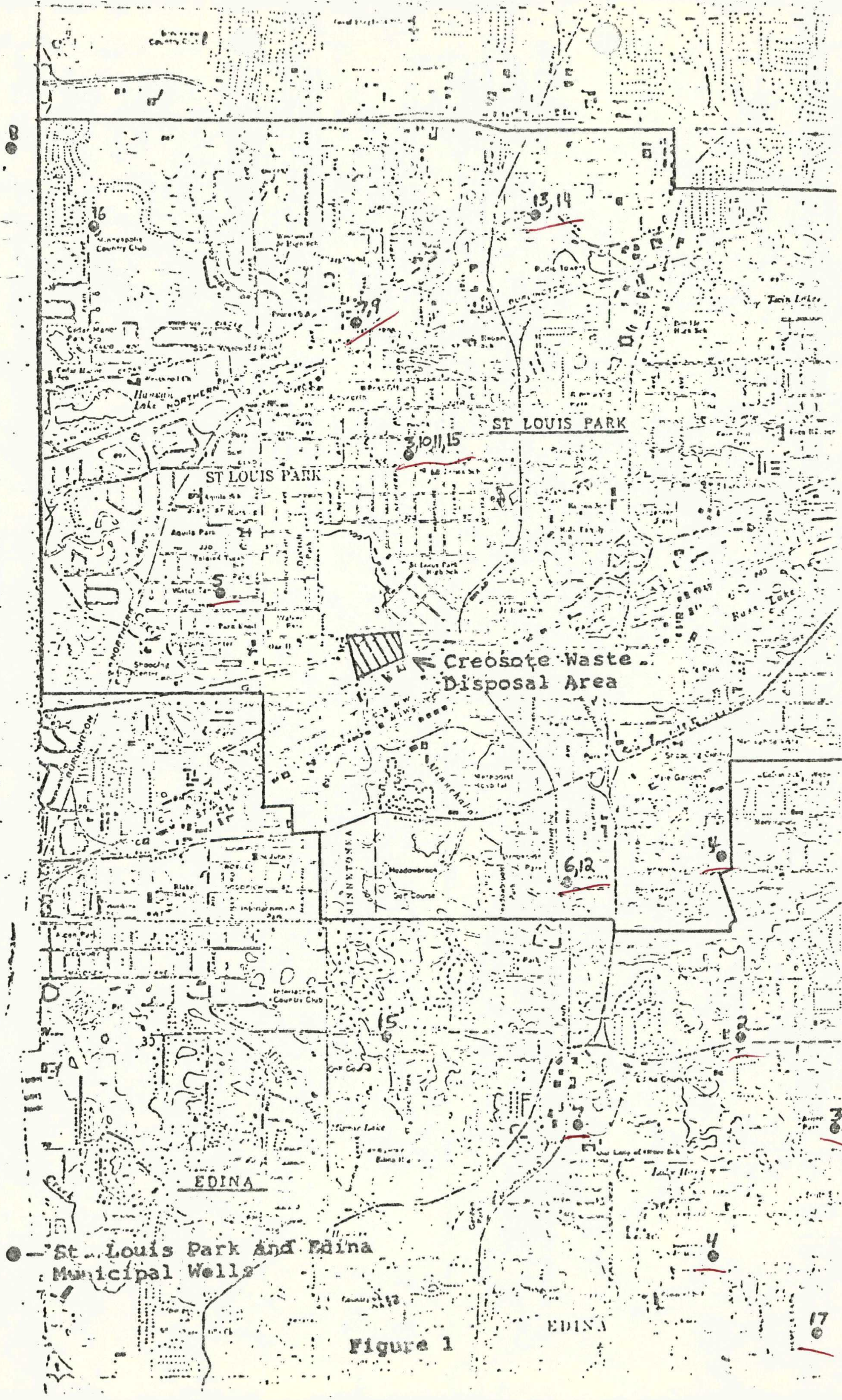
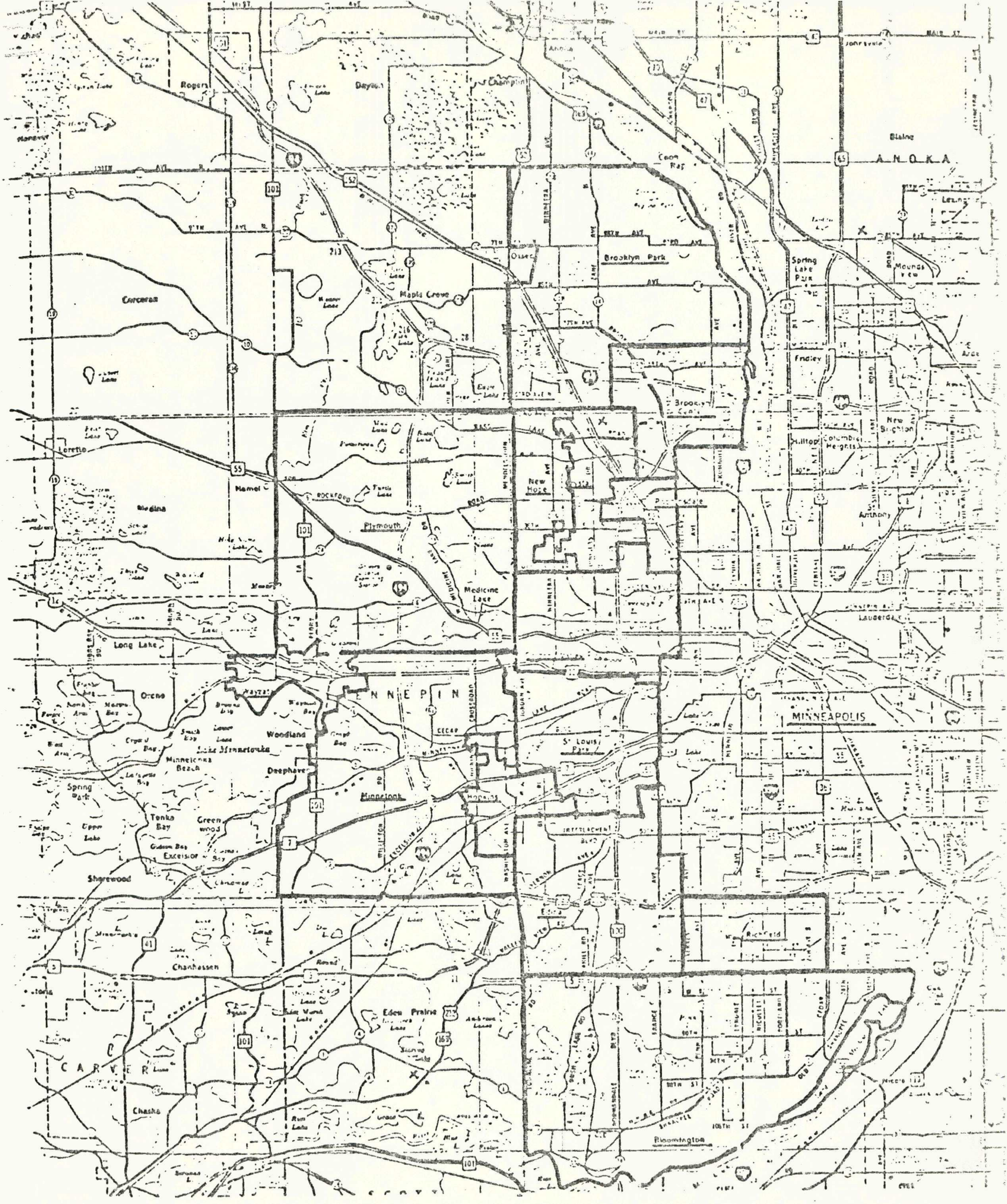

ST LOUIS PARK
ST LOUIS PARK
Creosote Waste Disposal Area
EDINA
EDINA
13,14
16
7,9
3,10,11,15
5
4
6,12
15
2
3
4
17
8
St. Louis Park and Edina Municipal Wells

Figure 1



Rogers
Dayton
Champlin
Anoka
Blaine
A N O K A
Coon Rapids
Brooklyn Park
Osseo
Maple Grove
Corcoran
Spring Lake Park
Mounds View
Fridley
New Brighton
Hilltop
Columbia Heights
Loretto
Hamel
Medina
Plymouth
New Hope
St. Anthony
Medicine Lake
Long Lake
Orono
Wayzata
Woodland
Lake Minnetonka
Minnetonka Beach
Deephaven
Minnetonka
Hopkins
St Louis Park
MINNEAPOLIS
Spring Park
Tonka Bay
Greenwood
Excelsior
Shorewood
Edina
Richfield
Chanhassen
Eden Prairie
C A R V E R
Chaska
Bloomington

Figure 2

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City of St. Louis Park, Minnesota

[redacted]

NON-RESPONSIVE

2. <u>Dates of Well Closures</u>

(a) Well 7 - September 29, 1978 (last run)

Well 9 - September 29, 1978 (last run)

Well 10 - November 10, 1978

Well 15 - November 10, 1978

Well 4 - November 20, 1979

(b) <u>Reasons for Well Closures</u>:

During the period May 8 - August 9, 1978, water samples were analyzed for seven polynuclear aromatic hydrocarbons (anthracene, pyrene, fluoranthene, benzo(a)pyrene, benzo (ghi) perylene, o-phenylenepyrene, and naphthalene) for municipal wells serving St. Louis Park, Edina, Robbinsdale, White Bear Lake, Fridley, for four private wells in Edina, and for the Glenwood-Inglewood well in Robbinsdael. Samples were analyzed using High Performance Liquid Chromatography (HPLC), and positive results for pyrene, fluoranthene, anthracene, and naphthalene were confirmed by gas chromatography/mass spectrometry. Wells 10 and 15 were found to be most heavily contaminated and wells 7 and 9 were less heavily contaminated. All of these wells are Prairie du Chien-Jordan wells. Levels for pyrene fluoranthene, anthracene, and naphthalene were well above detection limits, while levels for benzo (a) pyrene, benzo (ghi) perylene, and o-phenylenepyrene were just above detection for St. Louis Park wells 7, 9, 10, and 15. Please refer to Table 1 for specific values. These four wells were closed because the potential intake of PAH compounds by St. Louis Park residents via water supply would be significantly increased over other sources (i.e. dietary). Secondly, the only standards on PAH levels in water at the time were World Health Organization standards, setting a level of 200 ng/l for the sum of six PAH compounds, including fluoranthene.

Well #4 was closed in the Autumn of 1979, because of the appearance of acenaphthalene, biphenyl, fluoranthene, phenanthrene, and benzo(a)pyrene during October and November samplngs. Please refer to Table 2 for analytical data.

(c) Well 4 was pumped on May 1 (311,000 gallons), May 3 (264,000 gallons), and May 5 (244,000 gallons) of 1980 in order to provide adequate pressure in the distirbution system of St. Louis Park for fire protection.

Wells 7, 9, 10, and 15 have never been in service. Well 15 has provided water to analyze the effectiveness of powdered activated carbon slurry treatment. Tests were conducted during July and October of 1979. All waters from Well 15 were discharged to wastes.

(d) Well 4 was placed into service because the City was facing a low-pressure condition in the distribution system in the southeast corner of St. Louis Park. This condition presented a particular problem in providing adequate fire protection. The well was operated on three (3) separate days.

3. (a) A brief study was conducted on treatment of contaminated water utilizing a small-scale, pilot treatment plant using powdered activated carbon (PAC) Tests were conducted during July (7/16/79 - 7/20/79) and October (10/2/79) of 1979.

(b) Powdered activated carbon (PAC) served as a media for absorption of PAH compounds. PAC was mixed with water to form a slurry, which was then pumped into the well head of well 15. The well was pumped at 1000 gpm. PAC levels of 1-2 mg/l, 4-5 mg/l and 9-12 mg/l were analyzed. PAC was removed on sand filters and the waters discharged to waste.

(c) The treatment studies conducted to date have indicated strong removal of PAH compounds, and have been very encouraging. Reductions of greater than an order of magnitude have been found, particularly for PAC concentrations of 9-12 mg/l. However, some of the results have been erratic and clearly a well-structured and intense study is required to determine the long-term effectiveness of the treatment system.

(d) The treatment studies have not had any impact on the water supply to date. The studies that were conducted were preliminary and further work is required before allowing treated water into the distribution system. The waters pumped from well 15 have been discharged to waste following treatment and sampling. Water from wells 7, 9, 10, 15, have never been used for supply and from well 4 for a brief period in early May.

(e) The City of St. Louis Park has retained a consultant (Hickok & Associates) to provide technical and economic information necessary to design and implement a carbon treatment system. Both powdered activated carbon and granular activated carbon will be investigated include interconnection with other municipal súpplies (i.e. Minneapolis), deepening and reconstruction of existing wells, and dilution of contaminated water with uncontaminated water. This information will be completed by the end of 1980.

4. Contamination of the groundwater was first suspected in 1932 when the City of St. Louis Park constructed the first municipal well - a 16 inch, 540 deep well cased to 280 feet. (Shortly after well development, the water developed a pronounced taste and odor of creosote and the city had to abandon the well. This location is 3000 feet east of the Republic Creosote facility.

Contamination of all drift and bedrock aquifers has been identified. There are three primary sources of contamination:

(a) Spills and drippings on the site, with infiltration of contaminants affecting groundwater on the site.

(b) Surface runoff and waste discharges draining into a swampy area immediately south of the Republic Creosote facility.

(c) Entrance of coal-tar directly into deep well on the Republic Creosote site and transport via uncased, multi-aquifer wells.

Sometime during the 1920's coal tar was introduced into the deep water supply well (909 feet deep) on the Republic site. This well penetrates through to the Mt. Simon-Hinckley aquifer and was originally open-hole through all the bedrock units. When the well was examined in 1979, the well was plugged at a depth of 595 feet with coal-tar. To complicate matters, groundwater flowed from the St. Peter Sandstone through the well bore into the Prairie du Chien-Jordan system, at an estimated flowrate of 150 gpm. A packer was placed in this well to eliminate this flow.

The Drift-Platteville aquifer system is contaminated at least one mile to the east and southeast from Republic Creosote. Heaviest contamination appears to be in the swampy area between Lake and Walker Streets, immediately south of the facility. In this area, visible creosote-like oils are found to depths of fifty feet.

Contamination is the Prairie du Chien-Jordan system has extended at least 2 miles to the north (closing wells 7, 9, 10, 15) and at least 1½ miles to the east and southeast (closing well 4). The western distribution is unknown at this time. Although the regional flow direction of this aquifer system is to the southeast, local pumping centers appear to be primarily responsible for contaminant movement. As contaminated wells closer to the site are closed, contamination appears to move toward outlying, active wells. This appears to have been the case with well 4 which gradually became contaminated after municipal wells 7, 9, 10, 15 and some industrial wells were closed. Now that well 4 is closed, well 6 may become contaminated.

The extent and magnitude of contamination in the Franconia-Ironton-Galesville aquifer system and the Mt. Simon-Hinckley aquifer system are not well-defined at this time. Clearly, there is a source of contamination to these aquifer systems through the deep well on the site containing coal-tar and through multi-aquifer wells penetrating the Prairie du Chien-Jordan system. Municipal wells 11, 12, and 13, which draw from the Mt. Simon-Hinckley system, have no indications of contamination. There are few monitoring or private wells penetrating through these deeper aquifers, and so it is difficult to assess the extent of contamination.

(Table 2)

TABULATION SHEET

TOPIC St. Louis Park Municipal Wells.

	date of sample	lab number	total volume pumped in previous 24 hours	2-methylnaphthalene	acenaphthalene	biphenyl	anthracene	phenanthrene	pyrene	1,2,6,7-tetrahydropyrene	fluorene	fluoranthene	1,2-benzanthracene	chrysene	benzo (a) pyrene	9,10-benzphenanthrene	benzo (e) pyrene	perylene	benzo (g,h,i) perylene	benzo (k) fluoranthene	benzo (j) fluoranthene	o-phenylene pyrene	1,2,3,4-dibenzanthracene
			x 1000 gal.	nanograms/liter = parts per trillion																			
St. Louis Park #4	10-19-79	6563			230.	47.		66.	87.			5.8	<3.8	3.6	<5.4			<2.2				<2.6	<4.1
St. Louis Park #6	10-19-79	6564			<24.	<5.5		<2.4	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.1
St. Louis Park #8	10- 9-79	6565			<24.	<5.5		5.8	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.1
St. Louis Park #11	10-19-79	6566			<24.	<5.5		<2.4	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.
St Louis Park #12	10-19-79	6567			<24.	<5.5		<2.4	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.
St. Louis Park #13	10-19-79	6568			<24.	<5.5		<2.4	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.
St. Louis Park #4	11-8-79	7114			<120.	34.		36.	<17.			3.5	<4.0	<4.0	<6.0			<3.4				<2.8	<4.
St. Louis Park #15	11-8-79	7115			<600.	1300.		1000.	<84.			450.	40.	<20.	30.			<17.				<14.	<20.
St. Louis Park #4	11-16-79	7386			300.	19.		43.	<14.			1.9	<3.2	<3.8	7.4			<4.2				<3.0	<3.
St. Louis Park #4	11-16-79	7387			290.	18.		44.	<14.			2.0	<3.2	<3.8	12.			<4.2				<3.0	<3.
St. Louis Park #4	11-16-79	7388			290.	16.		40.	<14.			2.4	<3.2	<3.8	<6.4			<4.2				<3.0	<3.
St. Louis Park #4	11-16-79	7389			280.	17.		42.	<14.			3.1	<3.2	<3.8	<6.4			<4.2				[illegible]	<3.
St. Louis Park #7	11-5-79	7396			<100.	<24.		<10.	← +			<17.	<24.	<15.	<24.			<16.				<12.	<16.
St. Louis Park #9	11-5-79	7397			<100.	<24.		<10.	← +			<17.	<24.	<15.	<24.			<16.				<12.	<16.
St. Louis Park #10	11-5-79	7398			<100.	930.		690.	← +			810.	65.	<15.	44.			<16.				<12.	<16.
St. Louis Park #15	11-5-79	7399			<100.	1140.		1000	← +			550	53.	<15.	38.			<16.				<12.	<16.
St. Louis Park #14	10-19-79	6569			39.	11.		12.	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.1
St. Louis Park #15	10-19-79	6570			<120.	<28.		1300	<70.			830.	39.	<18.	<27.			<11				<13.	<20
St. Louis Park #16	10-19-79	6571			<24	<5.5		6.0	<14.			<3.7	<3.8	<3.6	<5.4			<2.2				<2.6	<4.1
St. Louis Park #15	7-16-79	55087		<67.	3200	← +		1700	← +			510.	<52.	<25.	<2.2	<15.		<1.0				<1.0	<38.
St. Louis Park #15	7-18-79	55095		<67.	2400	← +		1800	← +			440.	<52.	<25.	<2.2	<15.		<1.0				<1.0	<38.
St. Louis Park #15	7-19-79	55102		<67.	2800	← +		1900	← +			380.	<52.	<25.	<2.2	<15.		<1.0				<1.0	<38.
St. Louis Park #15	7-20-79	55123			<2.2	450.	60.	1400	← +			190.			<2.2	<1.0		<1.0				<1.0	<1.0

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